Long-term Comparative Outcomes of All-Inside Versus Inside-Out Repair of Bucket-Handle Meniscal Tears

A Cohort Study

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Background: Bucket-handle meniscal tears (BHMTs) are a common subtype of meniscal tears that represent a clinical challenge. Arthroscopic inside-out repair has been considered the gold standard in treatment; however, an all-inside approach has gained widespread popularity, with limited long-term evidence.

Purpose/Hypothesis: The purpose of this study was to (1) compare long-term clinical outcomes and rates of failure after surgical repair of BHMTs using the all-inside versus inside-out technique, and 2) identify risk factors for failure at long-term follow-up. It was hypothesized that clinical outcomes and rates of failure would be similar between the 2 techniques.

Study Design: Cohort study; Level of evidence, 3.

Methods: Patients who had undergone surgical repair of BHMTs between 2003 and 2013 at a single institution were identified. Patient-reported outcome measures (PROMs) were assessed preoperatively and at the latest follow-up using the Tegner scale, International Knee Documentation Committee questionnaire, and visual analog scale pain at rest and with activity. A univariate Cox proportional hazards model was used to identify predictors for repair failure, defined as revision meniscal surgery and/or documented meniscal retear.

Results: In total, 63 patients were included (37 with inside-out repair, 26 with all-inside repair). At a mean follow-up of 11.2 years, the survival rate for BHMT repair was 63% overall, 70% for all-inside repairs, and 60% for inside-out repairs ($P = .37$). The mean time to failure was 2.6 years for all-inside repairs and 2.5 years for inside-out repairs ($P = .98$). PROM scores were not significantly different between the 2 repair groups ($P > .22$). Univariate Cox proportional hazards model for failure demonstrated that increasing age at surgery was associated with lower failure rates (hazard ratio, 0.91 change per 1-year increase in age; 95% CI, 0.84-0.98) and medial meniscus repair was associated with higher failure rates (hazard ratio, 3.12; 95% CI, 1.14-8.77).

Conclusion: Long-term follow-up of BHMT repair demonstrated satisfactory clinical outcomes and failure rates. In appropriately selected patients, the all-inside technique did not compromise outcome as compared with the inside-out repair techniques. For both methods, older age was associated with lower failure rates and medial meniscus repair was associated with increased failure.

Keywords: bucket-handle tear; meniscal preservation; meniscal repair; knee

Bucket-handle meniscal tears (BHMTs) are a common subtype of meniscal tears that represent a clinical challenge. These tears generally occur in young athletes in a traumatic setting but also occur in the general population. Traditionally, an arthroscopic inside-out approach for repair of these tears has been considered the gold standard in treatment.[20,28,31] In recent years, an all-inside approach has gained traction because of purported convenience and versatility. Commonly cited reasons for the all-inside repair include, but are not limited to, potentially decreased operative time, lack of a need for an incision or a second assistant to retrieve sutures, and potentially reduced

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neurovascular complications.[45] Notably, all-inside repair poses a theoretical increase in cost because of the need for specialized, historically more expensive instrumentation. Both techniques have unique benefits and drawbacks.

Biomechanical studies in a cadaveric model have demonstrated similar outcomes with respect to load to failure with both the all-inside and inside-out techniques.[6] Previously published literature has also comprehensively established short-term and midterm clinical outcomes for the 2 approaches. A systematic review by Grant et al[16] identified 19 studies reporting on clinical outcomes of both all-inside and inside-out BHMT repairs with a maximal comparative follow-up of 6.5 years. No statistically significant difference was found between the cumulative failure rate of the all-inside technique from 7 studies (20/105; 19%) and the cumulative failure rate of the inside-out technique from 5 studies (20/119; 17%). Comparable short-term and midterm follow-up results have continued to be demonstrated in subsequent follow-up systematic reviews and primary studies, although it is important to consider these results in light potential conflicts of interest that may arise among authors who may benefit from demonstrating noninferiority of devices in whose development they participated.[4,13,43,44] Although not the focus of this study, it is worth mentioning that some studies have demonstrated that outside-in repair may have superior meniscal healing rates.[11]

We previously demonstrated in a rigorously matched cohort study comparing all-inside versus inside-out repair of BHMTs that there were no differences in patient-reported outcomes or revisions at a mean 4.4-year follow-up.[36] Since then, there has been little evidence for superiority of either approach in clinical practice, and the decision to pursue one or the other has been primarily clinician practice dependent.[45] Of note, it is increasingly understood that lateral meniscal repairs and repairs associated with concomitant anterior cruciate ligament (ACL) reconstruction (ACLR) demonstrate overall superior outcomes as compared with isolated meniscal repairs.[44] However, there remains a paucity of available comparative literature at long-term follow-up analyzing repair of BHMTs in isolation from other meniscal tear classifications.[36]

The purpose of the current study was to (1) compare long-term clinical outcomes and rates of failure after surgical repair of BHMTs using the all-inside versus inside-out technique and (2) identify risk factors for failure. We hypothesized that clinical outcomes and rates of failure would be similar between the 2 techniques in accordance with previously published shorter-term follow-up data.

METHODS

After receiving institutional review board approval, we identified a cohort of 70 patients who had undergone surgical repair of BHMTs by the senior authors (B.A.L., M.J.S., and A.J.K.) between 2003 and 2013. This time frame was selected because it marks the adoption of second-generation all-inside suture devices by the senior authors.

Patient Selection

Inclusion criteria were patients with BHMTs who underwent repair. Indications for repair consisted of reducible full-thickness tears with or without concomitant ACLR. Repair technique choice was at the discretion of the operating surgeon. Exclusion criteria were patients who had (1) not consented for research follow-up, (2) <2 years of follow-up, (3) grade 4 chondromalacia, (4) knee dislocations, (5) combined ACL and posterior cruciate ligament injuries, (6) previous repair of the ipsilateral meniscus, and (7) fixation with first-generation all-inside devices. Patients with repairable degenerative meniscal tears without any reported trauma were included in our analysis. No surgical age limit was implemented. This previously identified cohort was then followed for the duration of the study period.

Surgical Technique

All BHMT repairs were performed by 1 of 3 fellowship-trained sports medicine orthopaedic surgeons at our institution (B.A.L., M.J.S., and A.J.K.). After preparation and sterile draping of the patient, conventional arthroscopic portals were introduced. In the case of the inside-out techniques, either a medial or lateral incision was introduced to facilitate suture passage and retrieval. The decision to repair the meniscus using an all-inside or an inside-out approach was ultimately up to the surgeon's discretion and preference.

All diagnoses of BHMT were confirmed under direct arthroscopic visualization. The indication for BMHT repairs was a confirmed diagnosis with intraoperative probing and inspection demonstrating tissue quality amenable to repair. Of note, it is our institutional preference to attempt repair of meniscal tears when possible. If the tear was deemed amenable to surgical repair, the meniscus underwent debridement and rasping with an arthroscopic

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Ethical approval for this study was obtained from Mayo Clinic (ref No. 15-000601).

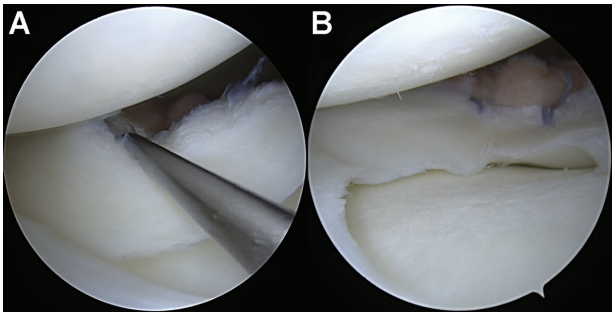

Figure 1. (A) Arthroscopic view of right knee from anterolateral portal with probe in anteromedial portal demonstrating large, unstable posterior horn lateral meniscus tear. (B) Arthroscopic view of the same knee from an anteromedial portal showing repair with 2 all-inside devices for the posterior horn (FiberStitch; Arthrex).

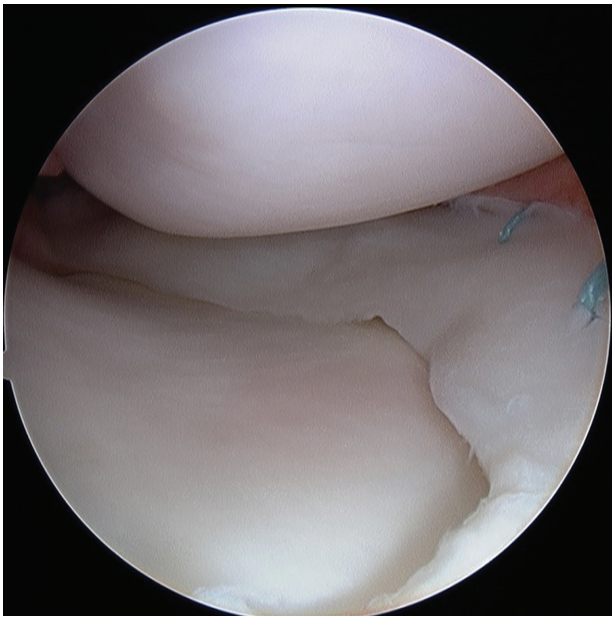

Figure 2. Arthroscopic view of the right knee demonstrating vertical mattress repair utilizing the inside-out technique for vertical longitudinal tears.

shaver or rasp to promote bleeding and healing. Scar tissue was resected as necessary to facilitate reduction. Tears were repaired utilizing the all-inside technique used a vertical mattress suture configuration in accordance with guidelines from the respective medical devices (Figure 1). Patients received either an anchor-based or cinch construct. Of the 29 patients who received all-inside repairs, 3 received a meniscal cinch (Meniscal Cinch; Arthrex) while 26 received anchor constructs (Fast-Fix 360; Smith+Nephew). Tears reduced with the inside-out technique used a vertical mattress suture configuration, spaced between 5 and 7 mm apart or however deemed necessary for meniscal stability, with No. 2-0 nonabsorbable sutures (Ethicon) to approximate the superior and inferior leaflets (Figure 2).

Postoperative Rehabilitation Protocol

All patients at our institution follow a standard meniscal repair rehabilitation protocol. During the first 4 weeks postoperatively, patients with BHMT repairs were instructed to refrain from full weightbearing and restrict range of motion to 90° of flexion. Knee immobilizers were recommended for ambulation during this period. Patients subsequently progressed to full weightbearing as tolerated after the 4-week postoperative time point, and return to full preoperative activities without restrictions was permitted at 4 to 6 months postoperatively contingent on patient clinical progression. In meniscal repairs with concomitant ACLR, patient recovery was dictated by ACL rehabilitation protocol with immediate weightbearing permitted postoperatively.[45]

Patient Outcome Assessments

Patient electronic medical records were retrospectively reviewed for incidence of repair failure. Failure was defined as either meniscal retear requiring revision surgery or symptomatic image-documented repair retear that did not undergo intervention. Patients were contacted via email through our institutional Research Electronic Data Capture (REDCap Version 13.1.37; 2023 Vanderbilt University) system to capture patient-reported outcome measures (PROMs). These consisted of Tegner and International Knee Documentation Committee (IKDC) scores, which had been obtained from patients preoperatively as well. Patients who did not experience meniscal repair failure were asked to rate their initial surgery satisfaction on a scale of very dissatisfied, dissatisfied, neutral, satisfied, and very satisfied at final follow-up. Patients who did not respond to email surveys were subsequently contacted through telephone on at least 3 separate occasions by study investigators.

Statistical Analysis

An a priori power analysis with an alpha of .05 and power of 0.8 determined that 61 patients would be sufficient to detect a difference in failure rates of BHMT repair type assuming a true difference of moderate effect size were to exist ($\varphi = 0.36$).[10] Additionally, power analysis utilizing the same parameters determined that 48 patient responses would be adequate to demonstrate effect size utilizing the previously established minimal clinically important difference (MCID) for the IKDC score.[27]

Continuous variables were reported as means with standard deviations. A 2-tailed t test was conducted to determine any statistical difference between patient characteristics of the all-inside versus inside-out groups. Kaplan-Meier survival curves were utilized to demonstrate reoperation-free survival rates of all-inside versus inside-

out bucket-handle repairs. A Cox proportional hazards analysis was conducted to identify predictors for reoperation with respect to baseline patient and injury characteristics, with results reported as hazard ratios (HRs) and their 95% confidence intervals. Statistical significance was set at a P value $< .05$. Statistical analyses were conducted in the R statistical environment (Version 4.3.1; R Foundation for Statistical Computing) and G*Power (Version 3.1.9.6).[12]

RESULTS

Of the original cohort of 70 patients, 7 (10%) were lost to follow-up, resulting in a long-term follow-up rate of 90% (Figure 3). The remaining 63 patients (43 male and 20 female patients; mean age, 23.9 ± 7.5 years [range, 13-47 years]; BMI, 26.1 ± 3.9 kg/m^2) with BHMT repair were followed for a mean of 11.2 years (range, 9-14 years). Baseline patients characteristics were statistically similar between the inside-out repair group (n = 37) and the all-inside repair group (n = 26) (Table 1). Pertaining to injury characteristics, 9 of 26 (35%) all-inside repairs demonstrated a rim width ≥3 mm, while 19 of 37 (51%) inside-out repairs demonstrated a rim width ≥3 mm (P = .29). Of the all-inside repairs, 16 of 26 (62%) involved the lateral meniscus, while 12 of 37 (32%) inside-out repairs involved the lateral meniscus (P = .04). Complex tears were present in 10 of 26 (38%) all-inside repairs and in 17 of 37 (46%) inside-out repairs (P = .74). All-inside repairs utilized a mean of 4.7 ± 1.64 stiches, while inside-out repairs utilized a mean of 8.9 ± 3.45 stitches ($P < .01$).

The mean follow-up of the inside-out group was 11.4 years, while the mean follow-up of the all-inside group was 10.8 years (P = .15). At the final follow-up, no group differences were seen in Tegner (inside-out vs all-inside: 8.6 vs 8.5; P = .92), IKDC (79.4 vs 80.5; P = .83), visual analog scale (VAS) pain at rest (0.29 vs 0.47; P = .22), or VAS pain with activity (1.25 vs 1.67; P = .25) scores. The full patient characteristics and outcomes of both groups are presented in Table 1.

The survival rate for all BHMT repairs was 63% at a mean final follow-up of 11.2 years. The survival rates at 2-, 5-, and 10-year follow-ups were 84%, 81%, and 70%, respectively, for the all-inside group and 78%, 65%, and 60%, respectively, for the inside-out group, with no significant difference between the 2 groups (P = .37) (Figure 4). These findings corresponded to a mean time to failure of 2.6 years for the all-inside group and 2.5 years for the inside-out group (P = .98). No patients in this study population required meniscectomy or conversion to total knee arthroplasty after index meniscal repair.

Patient-Perceived Satisfaction

In response to satisfaction of their index surgery, of patients who did not experience construct failure in the inside-out cohort, 15 of 19 (79%) patients who responded indicated very satisfied and 4 (21%) indicated satisfied. Of patients who did not experience construct failure in the all-inside cohort, 12 of 16 (75%) patients who responded indicated very satisfied and 4 (25%) indicated satisfied.

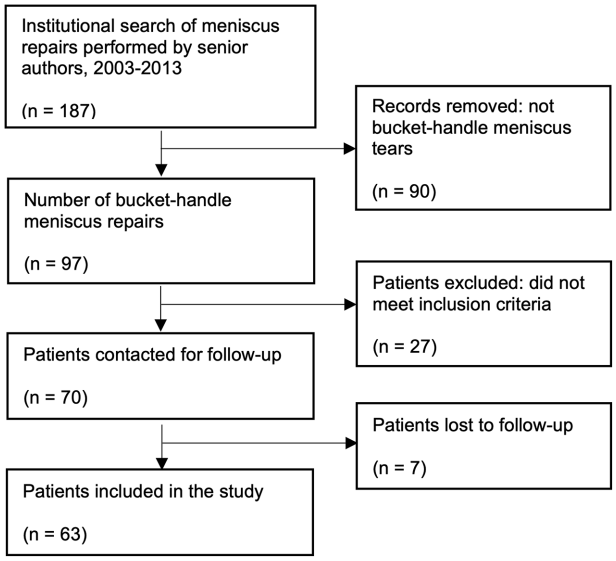

Figure 3. Flowchart of patient identification and inclusion.

Hazard Analysis

For all patients, a univariate Cox proportional hazards model for failure demonstrated increasing age as a significant correlate to decreased failure of surgical repair (HR, 0.91; 95% CI, 0.84-0.98; P = .02). Medial meniscal repairs were associated with increased failure of surgical repair (HR, 3.12; 95% CI, 1.14-8.77; P = .02). Repair type, sex, body mass index, rim width, and concurrent ACLR did not demonstrate significant effects on survival (Table 2).

DISCUSSION

The primary finding of this study was that at long-term follow-up (mean, 11.2 years), there were no significant differences in clinical outcomes or survival rate after comparing surgical repair of BHMTs between the all-inside and inside-out techniques. In both groups, increasing age was significantly associated with increased survival of surgical repair, and medial meniscus repair was associated with decreased survival of surgical repair.

At the final follow-up, we observed no appreciable differences between the repair groups in the Tegner, IKDC, VAS pain at rest, and VAS pain with activity scores. Our previous study from the same institutional population demonstrated a similar lack of discernable differences

TABLE 1
Patient Characteristics and Outcomes in the Inside-Out and All-Inside Repair Groups[a]

	Inside-Out Repair (n = 37)	All-Inside Repair (n = 26)	*P*
Age at surgery, y	24.9 ± 7.6	23.1 ± 7.5	.33
Time to surgery, days	29 [16-83]	23 [12-83]	.77
Sex			.89
Male	25 (68)	18 (69)	
Female	12 (32)	8 (31)	
Body mass index, kg/m^2	25.6 ± 4.0	26.9 ± 3.6	.18
Smoker	2 (5)	5 (20)	.09
Preoperative Tegner score	2.2 ± 1.0	2.27 ± 1.4	.84
Preoperative IKDC score	36.6 ± 14.2	34.3 ± 11.0	.52
Rim width, mm			.29
<3	18 (49)	17 (65)	
≥3	19 (51)	9 (35)	
Complex tear			.74
Yes	17 (46)	10 (38)	
No	20 (54)	16 (62)	
Meniscal repair			**.04**
Lateral	12 (32)	16 (62)	
Medial	25 (68)	10 (38)	
No. of stitches	8.9 ± 3.45	4.7 ± 1.64	**<.01**
Concurrent ACLR			.17
No	27 (73)	14 (54)	
Yes	10 (27)	12 (46)	
Reoperations	15 (40)	8 (31)	.43
Follow-up (mean, 11.2 y)	n = 19	n = 16	
Tegner score	8.6 ± 1.4	8.5 ± 1.5	.92
IKDC score	79.4 ± 12.7	80.5 ± 15.7	.83
VAS pain at rest	0.29 ± 0.47	0.47 ± 0.90	.22
VAS pain with activity	1.25 ± 1.40	1.62 ± 1.80	.25

[a]Data are presented as mean ± SD, median [IQR], or n (%) unless otherwise indicated. Boldface *P* values indicate a statistically significant difference between groups ($P < .05$). ACLR, anterior cruciate ligament reconstruction; IKDC, International Knee Documentation Committee; VAS, visual analog scale.

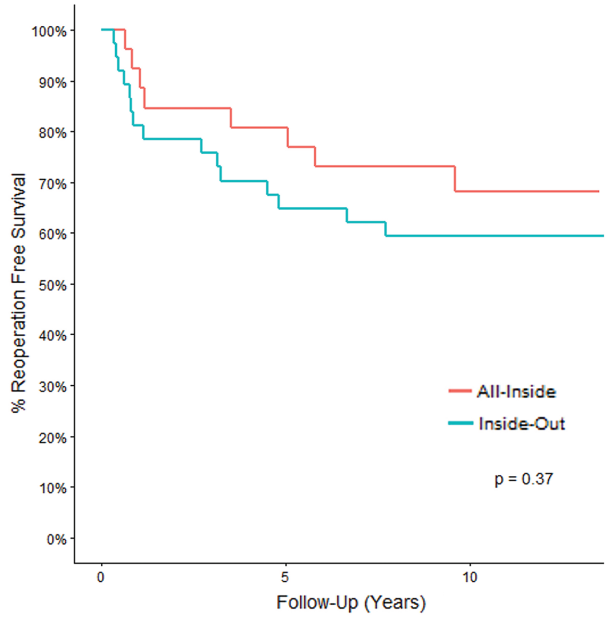

Figure 4. Kaplan-Meier estimator of reoperation-free survival.

TABLE 2
Univariate Cox Proportional Hazards Model for Failure[a]

	HR (95% CI)	*P*
Repair type		
Inside-out	Reference	
All-inside	0.97 (0.39-2.44)	.96
Age at surgery, y[b]	0.91 (0.84-0.98)	**.02**
Sex		
Female	Reference	
Male	1.10 (0.42-2.89)	.84
Rim width, mm		
<3	Reference	
≥3	1.05 (0.43-2.56)	.91
Meniscal repair		
Lateral	Reference	
Medial	3.12 (1.14-8.77)	**.02**
Concomitant ACLR		
No	Reference	
Yes	0.70 (0.27-1.82)	.47

[a]Boldface *P* values indicate statistical significance ($P < .05$). ACLR, anterior cruciate ligament reconstruction; HR, hazard ratio.
[b]Change in HR per 1-year increase in age.

between BHMTs repaired using all-inside versus inside-out techniques. Similar findings pertaining to PROMs have been reported extensively in the literature. Both Grant et al[16] and Fillingham et al,[13] in their systematic reviews, demonstrated no statistically significant differences in postoperative Tegner and Lysholm scores between all-inside versus inside-out repairs at midterm follow-up.

Importantly, this study also demonstrated that at a mean follow-up of 11.2 years, the failure rates for all-inside versus inside-out bucket-handle meniscal repairs were not significantly different (30% and 40%, respectively). The failure rates were comparable to those in a long-term study by Kalifis et al,[19] who demonstrated a 33% construct failure rate of BHMT repairs at a median follow-up of 9.5 years, although the results in their study were not stratified by repair type. The rate of failure in the current study was lower when compared with that of Solheim et al,[41] who reported a failure rate of 48% (39/82) for meniscal repairs at a median follow-up of 10 years. Notably, Solheim et al analyzed meniscal repairs utilizing the first-generation RapidLoc device, which has been proven to be significantly inferior to the second-generation devices, whereas our study exclusively analyzed repairs conducted with second-generation all-inside devices.[4,24,25,43] The reasons for these results are multifactorial. These first-generation devices often used darts and arrows for fixation, which demonstrated potential for implant migration and protrusion from the meniscal tissue with a risk of chondral injury, particularly in circumstances of unabsorbed biodegradable implants.[3,7,15,34,38] Complications of earlier-generation arrow construct degradation and subsequent migration to subcutaneous tissue or other structures have also been well documented.[9,14,33] In contrast, second-generation all-inside devices primarily use suture for fixation, which reduces the risk of implant migration and chondral injury. Additionally, early adopters of the all-inside approach may have been limited by both experience with this new technique and device designs that increased technical difficulty, whereas the inception second-generation devices coincided with greater surgeon experience.[42]

We reported a higher failure rate for all-inside repairs (30%) compared with a 2023 study by Wright et al,[46] in which 69 patients with all-inside meniscal repair utilizing second-generation devices demonstrated a 13% failure rate at the 10-year follow-up. Importantly, there were some substantial differences between our patient cohort and that of Wright et al, which may explain the differences in reported failure rates. The patients in the current study were younger (23.1 $\pm$ 7.5 vs 26.1 $\pm$ 10.4 years for Wright et al) and demonstrated lower preoperative PROM scores, which may indicate a patient population with more severe injuries at baseline. Additionally, the majority of meniscal repairs in our patients were performed without concomitant ACLR, whereas all the patients in the study by Wright et al underwent repair with concomitant ACLR. Concomitant ACLR has been demonstrated to augment meniscal healing because of the increase in blood and growth factors released during the procedure, in addition to greater postoperative restrictions.[2,17,21,29,32]

The number of sutures was significantly different between the 2 study groups in the current study. Given that it was up to the surgeon's discretion to utilize all-inside versus inside-out approaches, larger tears may have been treated inside-out, thereby requiring more sutures. This may have been a result of the limitation in device technology at the time of surgery, as there were fewer curvature options for all-inside devices, making it more challenging to reach far peripheral aspects of meniscal tears, particularly anteriorly. However, with the advancements of all-inside device constructs, these limitations are present to a lesser degree with modern all-inside instrumentation.

Cox hazard analysis demonstrated older age to be significantly associated with lower rates of construct failure and medial meniscus repairs to be significantly associated with higher rates of failure. A potential explanation for the effect of age is the increased mechanical demand on the meniscus, particularly in younger populations. Indeed, studies analyzing risk factors for meniscal repair failures have demonstrated increasing age as a protective factor against reinjury.[23,26] Pertaining to the differences in failure rates between medial and lateral meniscus repairs, higher rates of failure in medial repairs have been demonstrated by Nepple et al[30] in a systematic review and meta-analysis of 678 medial and 328 lateral repairs with an aggregate failure rate of 23.9% and 12.6% ($P = .04$), respectively. Proposed explanations for this phenomenon are increased biomechanical stress exerted on the medial versus lateral compartment, less mobile and more rigid anatomic anchoring of the medial meniscus to the tibial plateau, and significant anatomic differences between the 2 compartments resulting in more difficult access and lesser meniscal blood supply to the medial meniscus.[1,8,40] Previously published literature on failure rates of all-inside constructs has demonstrated better long-term outcomes in female patients, which may be attributed to a difference in activity and lifestyle.[35,41] Other factors that have demonstrated correlation with failure rates are concomitant ACLR, which has been shown to improve meniscal repair outcomes,[2,17,21,29,32] and rim width >3 mm, which has been shown to be a significant risk factor for worse outcomes.[18,22,37] Of note, nonstatistically significant correlations trended toward expected results based on previously published studies.

This study analyzing the long-term outcomes of all-inside repair, utilizing data from second-generation devices, adds to the growing body of evidence supporting the use of an all-inside technique for BHMTs. Additionally, older first-generation all-inside repairs have also demonstrated comparable clinical outcomes.[4,16,43,44] We provide further support for its continued use considering potential convenience and ease of use and the potentially decreased risk for neurovascular injuries.[5,16,39]

Limitations

This study should be interpreted in light of its limitations. First, as the study was not prospectively randomized, there may be bias in selecting a technique based on patient presentation and surgeon preference. Similarly, there is subjectivity with respect to what constitutes an irreparable

meniscal tear. PROMs and lack of failure were used as a proxy for meniscal healing as compared with second-look arthroscopy. Postoperative knee magnetic resonance imaging scans were not obtained on a standardized basis, and thus a radiological assessment of repair failure was precluded in our analysis. Although baseline patient characteristics were similar, injury characteristics demonstrated some minor differences, with a higher proportion of lateral meniscus repairs in the all-inside group. Additionally, higher rates of concomitant ACLR, albeit not statistically significant, were performed in the all-inside group. These factors may have comparatively improved meniscal healing and survival in the all-inside group. While the univariate Cox hazard analysis was utilized to account for this, it should still be interpreted in the context of a relatively small sample size. Last, although we found that the number of patients we analyzed was powered to detect the MCID for IKDC, it may have been underpowered for detecting significance in the univariate Cox proportional hazards model with respect to the variables of sex, rim width, and concomitant ACLR. Additionally, our analysis may have been underpowered to find a difference in failure rates between the 2 groups if the statistical effect size (φ) was small.

CONCLUSION

This long-term follow-up study of BHMT repairs demonstrated satisfactory clinical outcomes and failure rates in all patients. In appropriately selected patients, the all-inside technique did compromise outcome as compared with the inside-out repair technique. Older age was associated with lower failure rates for both methods, and medial meniscus repair was associated with increased failure.

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